INSECT AND DISEASE CONSIDERATIONS FOR THE IDAHO PANHANDLE NATIONAL FORESTS PLAN

By

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INTRODUCTION

Insects and diseases are natural factors within forest ecosystems and must be considered when formulating plans for management of such systems. Intensity of buildup and subsequent losses caused by insects and diseases can often be directly linked to treatments of forest stands. Before treatments are implemented, forest managers must be cognizant of the potential influences on natural biological balances and impacts.

The following insect and disease problems have current or potential effects on management options and decisions within the Idaho Panhandle National Forests:

1. Root Diseases
2. Dwarf Mistletoes
3. White Pine Blister Rust
4. Stem Decays
5. Western Spruce Budworm
6. Douglas-fir Tussock Moth
7. Larch Casebearer
8. Mountain Pine Beetle
9. Spruce Beetle
10. Douglas-fir Beetle
11. Fir Engraver
12. Seed and Cone Insects

None of these pests currently affect management policy to the degree of being major concerns in forest planning processes. However, several seriously impact management, especially on a localized basis, and may account for disparity between expected production and actual yields. Each pest is briefly described as to its current status on the forest, present and potential damage, and possible management strategies for reducing future losses.

ROOT DISEASES

Root disease may be the most serious long-term pest problem on the Idaho Panhandle National Forests. Extensive tree mortality and growth loss occur over long periods of time as a result of root disease. Although common in most habitat types, root diseases are especially prevalent within Douglas-fir and grand fir types. Surveys using large scale aerial photography indicate that over 16,000 hectares (1.9 percent) of commercial forest land on the Forest are occupied by large root disease centers (table 1) (Williams and Leaphart, 1978; Williams, unpublished). This estimate includes only large, distinct disease centers with active tree mortality. Common scattered small group or individual tree mortality attributable to root disease is not included. Losses in stands currently classified as noncommercial are also excluded from these estimates.

Table 1. Area of root disease centers within commercial forest stands on the Idaho Panhandle National Forests.

Unit	Total commercial area (ha)	Area with root disease centers (ha)	Percent commercial area with root disease centers
Coeur d'Alene	238,441.1	12,160.7	5.1
Kaniksu	315,027.5	2,669.4	0.8
St. Joe	300,261.8	1,367.9	0.5
Total	853,730.4	16,198.0	1.9

Trees weakened by root disease are often attacked by bark beetles (James and Goheen, 1981; Lane and Goheen, 1979). Douglas-fir with root disease is commonly attacked by the Douglas-fir beetle (*Dendroctonus pseudotsugae*); the fir engraver (*Scolytus ventralis*) often attacks diseased grand fir. Insect infestation is usually much easier to diagnose than root disease. As a result, root disease is often overlooked and not considered in stand treatments. Disease problems may therefore be perpetuated or increased because of improper pest diagnosis.

Large root disease centers identified by the surveys may be of limited productivity in the future because of persistence of pathogens on infected sites for many years (Shaw, 1980; Wallis, 1976). If disease-susceptible trees regenerate infected sites, such trees will probably

die before reaching maturity. These trees also perpetuate the problem by providing susceptible host material so that root pathogens can be maintained on sites. Root pathogens would die out over a period of decades in the absence of suitable host material. Therefore, without treatments aimed at altering this cycle, infected sites might remain "out of timber production" indefinitely.

Many root disease centers revert to brush fields because of continued conifer regeneration mortality. Such sites are usually not successfully planted with susceptible trees and may comprise important portions of the regeneration "backlog" in certain areas.

Root disease problem areas should be identified in relation to the role of disease in limiting regenerative capacities and projected future fiber production. This is necessary to preclude over-optimistic projections of expected future production where actual yields fall short of expected values.

Probably the most serious root pathogen on the Forests is Phellinus weirii, which causes laminated root rot of Douglas-fir and grand fir (Wallis, 1976). This fungus causes many of the large expanding disease centers on the Forests. Experience with P. weirii in Oregon and Washington indicates that management to reduce disease losses is very difficult and expensive (Childs, 1970). Other major root pathogens include Armillaria mellea and Phaeolus schweinitzii on all conifers, Fomes annosus on grand fir, and black stain root disease (Ceratocystis wageneri) on ponderosa pine. Several of these organisms attack the same trees in successional patterns. Therefore, trees may be attacked by several root fungi followed by secondary bark beetles, together forming pest "complexes" which lead to tree mortality (James and Goheen, 1981).

Root diseases are often more serious in plantations than natural stands; losses can especially be high if nonadaptive seed sources are used for planting stock. Trees of poor vigor or site adaptability are often more successfully attacked by root pathogens (Smith and Graham, 1975; Morrison, 1976).

Future losses to root diseases on the Idaho Panhandle National Forests will be a function of management direction in areas where disease levels are high and stands are susceptible. In general, losses increase as management intensifies, especially if number of stand entries are increased and root diseases are not considered in silvicultural prescriptions. The following discussion focuses on management direction and alternatives available for reducing root disease losses. Unfortunately, guidelines cannot be applied uniformly throughout the Forest; individual stands must be evaluated as to current disease levels and potential for future impact.

Economic losses from insects or diseases are a function of land management objectives. Commercial forest stands managed primarily for wood fiber production are probably most seriously impacted from root diseases. On the other hand, big game habitats may be improved because large root disease centers often provide continued browse production.

Management options to deal with root diseases in commercial timber stands include the following:

1. If nothing is done, mortality will probably continue as disease centers enlarge. Centers will become occupied with brush and some trees; productivity may be lost if centers regenerate with susceptible trees and mortality continues.

2. Dead and dying trees can be salvaged. Although rates of disease spread and tree mortality will not be reduced by salvage operations, recovery of potentially lost wood will be possible.

3. Infested areas can be regenerated with site-suited, less susceptible species. Not all conifer species are equally susceptible to root pathogens (table 2) (Filip and Schmitt, 1979). Many young stands can be grown to merchantability if disease tolerant species are favored. Less susceptible species can also be favored on the edges of and between disease centers.

4. Experimentation in stopping marginal spread of root disease centers and reclaiming these sites for future production has been tried in several areas with varied results (Wallis, 1976; Byler and James, 1981). Procedures include removal of all trees and stumps for a 1- to 2-chain radius around well defined root disease centers. Stumps and major roots are then removed from centers if sites are to be regenerated with susceptible species and returned to productivity.

5. Young stands with high levels of root disease should be thinned to favor least susceptible species.

6. Projected timber yields can be reduced. Present projections, based on inventory data, presumably account for losses in existing stands. However, inventory plots with regeneration will be projected at full production; such production is unlikely. Plots within non-stocked root disease centers may be planted and therefore projected at full capacity. Valid estimates of expected future yields on root disease infected acres are unavailable. However, it appears likely that future production will be drastically limited on at least the commercial acreage known to be within currently active disease centers (table 1).

Table 2. Relative susceptibility of selected conifer species to major root pathogens on the Idaho Panhandle National Forests. 1/

Pathogen	Tree species 2/		
	Most susceptible	Less susceptible	or resistant
Phellinus weirii	DF, GF	SAF, WH	WL, WWP, PP, SPP, WRC
Armillaria mellea	DF, GF, SAF, PP LPP 3/	WWP, WH, WRC	WL
Phaeolus schweinitzii	DF, GF, SAF, PP	WWP, WH (?) WRC (?)	WL
Fomes annosus	GF, SAF, PP, WH	DF, WRC, WWP LPP	WL
Ceratocystis wagenerii	PP, LPP, DF (?)	WWP	GF, SAF, WL, WRC, WH

1/ Most of the susceptiblility ratings are based on field observations rather than experimental data (Filip and Schmitt, 1979). (?) - indicates category based on "best guess" - actual susceptibility unknown.

2/ DF = Douglas-fir
GF = Grand fir
SAF = Subalpine fir
WH = Western hemlock
WL = Western larch
P = Western white pine
PP = Ponderosa pine
LPP = lodgepole pine
WRC = Western redcedar

3/ Although all these species are about equally susceptible to Armillaria, they are often not affected in the same disease centers, i.e., ponderosa pine are usually not killed in Armillaria centers where Douglas-fir and grand fir mortality occurs.

7. Root disease management research needs can be identified in forest plans. Little root disease research has been done in northern Idaho and none within Montana. It seems appropriate to identify research needs on:

a. The complex causes of root disease, and roles of individual pathogens.

b. Effects of silvicultural treatments, especially partial cutting, on root disease losses.

c. Stand hazard ratings for root disease.

d. Projections of losses in young growth stands, especially plantations.

e. Management techniques to reduce root disease losses, especially through use of more tolerant tree species.

The following factors should be considered when dealing with root diseases within and adjacent to developed sites and recreation areas:

1. Sites proposed for development should be carefully examined and root disease problem areas avoided.

2. All trees in developed sites should be inspected periodically. Those suspected to be root-diseased should be monitored and removed if they become hazardous.

3. Susceptible trees should be replaced with more disease tolerant species to maintain quality of developed sites.

DWARF MISTLETOES

Major dwarf mistletoes on the Forests include *Arceuthobium douglasii* on Douglas-fir, *A. americanum* on lodgepole pine, and *A. laricis* on western larch (Scharpf and Parmeter, 1978). Estimates of impact caused by these pathogens (table 3) indicate that about half the stands are affected and more than 9.7 MM cu. ft. of growth is lost each year (O. Dooling, unpublished). Systematic surveys to better quantify losses are scheduled to begin in 1981. Although the major effect of dwarf mistletoes is growth loss, severe infestations may result in premature tree death.

Table 3. Growth loss of Douglas-fir, lodgepole pine, and western larch caused by dwarf mistletoes on the Idaho Panhandle National Forests. 1/

Species	Percent stand infected	Volume loss ft^3/acre/yr.	Volume loss M ft^3/yr.
Douglas-fir	45	20	3,386
Lodgepole pine	50	10.1	788
Western larch	60	20	5,538
Total			9,712

1/ Estimates not obtained from systematic surveys; such surveys to begin in 1981.

Trees of all ages and sizes are susceptible to infection. Losses are usually greater on poor sites within dense, slow growing stands. Old growth stands on low productivity sites that were infected at an early age are most severely affected. Risk of infection is directly related to previous fire and cutting history. If infected trees remain on a site after harvest, there is a good chance the new stand will become infected.

Dwarf mistletoes can effectively be reduced through silvicultural treatments. Major management options include:

1. Regenerating infested stands using treatments which eliminate the pathogen.

2. Remove infected trees and improve tree growth by thinning.

3. Change stand composition to nonsusceptible hosts (dwarf mistletoes are generally host specific).

4. Remove infected residuals from logged or burned stands.

Seed tree and shelterwood treatments are suitable regeneration methods, provided overstory removal promptly follows establishment of regeneration. Lightly infected trees may be suitable crop trees if they can be released through thinning.

WHITE PINE BLISTER RUST

White pine blister rust, caused by the fungus *Cronartium ribicola*, is the most damaging disease of western white pine on the Idaho Panhandle National Forests. The disease has devastated many white pine stands throughout the Forests. Seedling, sapling, and pole-sized trees are most readily killed; larger trees are not killed as quickly and may often reach merchantable size.

High losses are expected to continue but probably at slightly decreased rates from the past. As more susceptible trees are killed, relative levels of stand resistance probably increases.

Past control efforts included attempts to eradicate the alternate hosts (*Ribes* spp.) and eliminate the fungus on infected trees with application of antibiotics. Both programs were unsuccessful; current management strategies include integration of genetic resistance with cultural treatments to minimize damage.

A tree improvement program to develop white pine with high levels of rust resistant stock is now underway; enough to meet all regional demands should be available in the near future. Resistant white pine is usually planted on rust susceptible sites in conjunction with other species to achieve mixed stands.

Although blister rust is more damaging than native rusts, trees which either escaped infection or are resistant are common in many stands. Many infected trees may continue to grow to merchantable size. Guidelines (table 4) have been developed to select leave trees during thinnings and seed tree-shelterwood harvest operations (Hoff and McDonald, 1977; McDonald, 1979). These guidelines are appropriate for both high and low hazard sites. On high hazard sites, most susceptible trees should be removed. On low hazard sites, natural selection will have been less vigorous, but less resistance is needed. Using these guidelines should result in maintenance of white pine as an important component of many stands.

Table 4. Guidelines for selecting white pine leave trees to minimize damage from blister rust. 1/

Age class	Mark trees that have:	Remove trees with:
Young (less than 30 yrs.)	No stem cankers Few or no branch cankers	Stem cankers Numerous branch cankers
Pole (30-60 yrs.)	Dense, luxuriant, grass-green foliage	Unthrifty, sparse, gray-green foliage
Mature (over 60 yrs.)	Vigorous crowns with few flags	Poor crown with flagging, dead tops and poor color

1/ Developed by Hoff and McDonald (Research Note INT-218).

STEM DECAYS

Stem decays are common in most forested areas and often cause significant volume loss in old growth stands. They also cause hazards in developed sites and recreation areas (Johnson and James, 1978). The two major decay organisms prominent on the Idaho Panhandle National Forests are *Phellinus pini* on Douglas-fir, western larch, ponderosa and lodgepole pine and *Echinodontium tinctorium* on true firs and western hemlock (Partridge and Miller, 1974).

Tree age and extent of residual tree wounding during entries are the two major factors dictating extent of decay within stands. Decays are common on wet, poorly drained sites at lower elevations, such as flats and bottoms. *Echinodontium tinctorium* can be a problem following release of infected regeneration.

Reducing losses from stem decays is primarily accomplished by removal of defective trees and prevention of damage to leave trees during stand entries. Highly susceptible stands should be grown on shorter rotations. Basal wounds are especially serious infection points for decay fungi. Number of stand entries should be limited in highly susceptible stands. Care should be taken to avoid injuring residual trees during such entries.

WESTERN SPRUCE BUDWORM, *Choristoneura occidentalis* Freeman

Budworm damage was first reported severely defoliating western hemlock and other conifers along Kalispell Creek near Priest Lake in 1922. Some hemlock was killed and the outbreak subsided in 1924. In 1963, heavy defoliation was again detected on the Priest Lake District, this time along the Washington-Idaho border. About 30,000 acres were defoliated in several drainages in the north fork Coeur d'Alene River during 1924, and from 1928 to 1933. Light defoliation occurred on scattered spruce trees on the Avery District during 1927 and 1928 (Johnson and Denton, 1975).

The most severe epidemic lasted from 1969 to 1978. More than 200,000 acres were defoliated on the Red Ives and Avery Ranger Districts. Grand fir was top killed and salvage logging was necessary. During 1980, defoliation was detected on 600 acres south of Avery.

In the mixed grand fir type on the St. Joe National Forest, grand fir is damaged the most followed by subalpine fir, spruce and Douglas-fir. Hemlock can be killed. Data from 73 stands showed that growth loss in terms of periodic annual increment ranged from 0 to 22.7 cubic feet/acre/year and averaged 5.3 cubic feet. Top killed trees averaged 88/acre and one stand contained 509 top killed trees/acre (Bousfield 1979).

On the Clearwater National Forest moderate top killed (10-33 percent crown length dead) grand fir lost 25.6 years' height growth in stands defoliated for 10 years.

Budworm is capable of infesting any diverse fir-hemlock stands. Weather plays an important role in triggering outbreaks. The droughts of 1967 and 1968 might have triggered the St. Joe epidemic.

Management Strategies and Alternatives

Although budworm epidemics have never been treated on the Idaho Panhandle National Forests, this method is still a possible alternative. Three registered chemical insecticides are malathion, carbaryl (Sevin®), and acephate (Orthene®).

Three silvicultural strategies for dealing with budworm are "salvage/presalvage", "reducing stand vulnerability," and "reducing stand susceptibility."

Salvage is the harvest of dead trees and living trees which are damaged beyond the point of recovery before resource values are lost or after some threshold of damage occurs. Since budworm is seldom directly responsible for mortality of merchantable sized trees, salvage volumes per acre are likely to be low with associated high logging costs. Presalvage is the harvest of trees which are expected to die or become

damaged beyond the point of recovery. Presalvage is implemented prior to an outbreak or before significant damage is apparent. Salvage and presalvage are suitable only for accessible stands where mortality and severe damage is concentrated. This is a simplistic silvicultural approach to budworm management, and caution should be exercised that stand degradation does not result.

Reducing stand vulnerability will prepare the stand for the next outbreak.

Vulnerability to budworm is a function of stand species composition and/or genetic composition, stand density, stand vigor, and stand size structure.

Host species vary in their ability to cope with defoliation. Grand fir suffers more top kill and radial growth reduction than associated Douglas-fir when subject to repeated budworm defoliation. Damage vulnerability is generally aligned with shade tolerance; it is always the more shade tolerant host species that suffers greater damage in mixed species stands. Two trees of the same species and size adjacent to one another may display different levels of defoliation, suggesting genetic resistance.

Stand density describes the absolute number of trees exposed to budworm feeding. Fewer host trees in the stand results in less damage. Trees in open stands are less defoliated than trees in dense stands.

Tree vigor influences vulnerability to budworm damage. Vigorous trees have more foliage per unit biomass and more carbohydrate root reserves than nonvigorous trees. Nonvigorous trees will have less remaining foliage than vigorous trees resulting in greater growth reduction for nonvigorous trees. Because of additional carbohydrate reserves, vigorous trees retain the ability to produce new foliage and recuperate once defoliation subsides. Vigorous trees are less affected by budworm outbreaks than nonvigorous trees.

Stand size structure is another important factor of vulnerability to damage. Larvae begin to drop on silken threads as food supply grows short in the upper canopy. Host understory receives increased feeding pressure from larvae dropping from the overstory. Understory trees are usually somewhat suppressed nonvigorous trees, and tend to have a greater proportion of their foliage in the current year age class because they're shaded. Loss of this foliage is particularly significant to these trees. Because of their position in the stand, and related condition, understory trees are very vulnerable to budworm damage with infested overstories. If crop trees are maintained in overtopped positions, the stand must be considered more vulnerable. To reduce vulnerability, the most vulnerable trees are removed during normal silvicultural treatments. Mixed species composition is favored in regeneration treatments; shade tolerant species are discriminated against. The least defoliated trees are

retained in partial cutting, thereby selecting for resistant genotypes. Even-aged systems are preferred over uneven-aged systems. Overstory removal cutting in seed tree and shelterwood systems is done promptly. Stand vigor is maintained by conducting appropriate thinnings. Host trees are harvested at maturity and diseased or otherwise damaged trees are removed.

The third silvicultural strategy addresses the question: How can the habitat of the budworm be manipulated to prevent insect population growth? Habitat factors that are both limiting to population growth and manageable are keys to preventing outbreaks.

Budworm populations are normally held to endemic levels by a complex of natural control factors including weather phenomena, natural enemies (parasites, predators, and pathogens), and the quantity and quality of available food. All too frequently favorable weather coincides with highly susceptible stand conditions and budworm populations expand rapidly, escaping the control of natural enemies. A series of perhaps 2-3 years with warm, dry weather in the spring and early summer is believed to be the climatic trigger for setting off outbreaks. Natural enemies are apparently unable to respond and suppress incipient outbreaks. If weather remains favorable, the epidemic will persist until budworm induces changes in stand conditions and depletes its food supply.

Stand susceptibility, which is both a measure of the probability of infestation and the intensity of attack is dependent on certain attributes of stands and the stands' orientation to dispersing larvae and adults. Larvae have feeding preferences which presumably reflect their nutritional needs. They don't like pine foliage, and do poorly on other than current year's host foliage. Both species composition and stand density are factors of stand susceptibility because they affect quantity and quality of food.

Stand density and species composition have an important influence on dispersal mortality. More larvae fall to the ground (where mortality is nearly certain) in open stands than in dense stands because trees are spaced further apart, airborne dispersal time is longer, and wind speeds are greater. In mixed species stands, more spring dispersing larvae are likely to encounter a nonhost which leads to starvation. Consequently, dense stands are more susceptible than open stands, and pure host stands are more susceptible than mixed nonhost stands.

Multilayered canopies provide additional feeding sites for dropping larvae, whereas single-storied stands offer a direct pathway to the ground. Uneven-aged stands are most susceptible.

As a stand matures, foliage biomass per acre expands and vigor begins to decline. Both quantity and quality of budworm food would tend to improve as stands grow older. Female budworm moths are known to prefer mature trees with large crowns for egg laying especially if foliage is exposed to the sun. Both feeding larvae and egg-depositing moths would view mature stands as better habitat than young stands. Since the crown exposure of dominant trees is usually greater in uneven-aged stands than even-aged, attraction to sunlit foliage for egg laying is a factor of susceptibility.

Prioritizing treatments on the basis of susceptibility is a viable approach to management. Removal of mature host trees around the perimeter of plantations will decrease larval dispersal into young stands. Creation of age classes and species composition will assure fewer potential epicenter stands contributing to outbreak developments. No such off-site benefits accrue by prioritizing treatments on a damage basis because the most susceptible stands are not necessarily the most vulnerable to damage.

Simultaneous implementation of all three silvicultural strategies is possible with the degree of emphasis shifting among them according to the rise and fall of budworm epidemics. Prioritizing harvests is reasonable in the face of an ongoing epidemic. Habitat management to prevent large scale outbreaks is good forest management. Coupled with the use of insecticides for selected resource protection, silvicultural strategies are the basis for integrated pest management.

DOUGLAS-FIR TUSSOCK MOTH, *Orgyia pseudotsugata* (McD.)

Since 1944, spot infestations and major epidemics have occurred each decade. Chronic outbreak areas are the Palouse, Clarkia, Fernan, Sandpoint, and Bonners Ferry Ranger Districts. The 1974 epidemic on the Palouse District was a public issue when 76,354 acres of mixed ownership were sprayed with DDT. No current infestations have been detected on the Forests.

Grand fir is the preferred host followed by Douglas-fir and spruce. All other conifers are susceptible during epidemics. Larvae can kill trees in one season. Bousfield and Ward (1976) found 17.6 percent of the Douglas-fir were killed and radial growth was reduced 30.9 percent in a stand on the Nezperce National Forest.

Models are available for predicting degree of defoliation, growth loss, top kill, and mortality based on larval populations and amount of defoliation. Trees weakened by heavy defoliation are susceptible to attack by fir engraver beetles, Douglas-fir beetles, and wood borers. Indexes have been plotted for mortality caused by bark beetles (Anon., 1978).

Outbreaks are cyclic, occurring at about 10-year intervals. The host type covers the Idaho Panhandle National Forests, but not all stands are susceptible. Stoszek (1978) rated high hazard stands based on five variables: (1) physiographic location - defoliation was heavier in stands on ridgetop or upper slope sites, (2) depth of volcanic ash - defoliation decreased as depth of volcanic ash increased, (3) site occupancy - defoliation increased as the ratio of total biomass to site productivity increased, (4) age of host trees - defoliation was not significant in stands with average age less than 50 years, and (5) proportion of grand fir - defoliation increased as the proportion of grand fir in the stand increased. Using these and other variables, stands can be risk rated for defoliation from aerial photographs (Heller and Sader, 1980). Kessler and others (1981) demonstrated this method on the Palouse Ranger District.

Infested ornamentals or shelterbelt trees are often indicators of outbreak development. Egg masses can be detected in foliage on tree-top slash. Pheromone baited traps are being used to catch male moths in the summer and aid in predicting population trends. Twenty-five or more male moths indicate potential visible defoliation within the next two summer seasons (Daterman and others, 1979).

Management Strategies And Alternatives

Past epidemics were treated with chemical insecticides. A management system has been developed that provides methods for predicting damage, weighing effects of different management practices, estimating costs of various treatments, and translating socioeconomic impacts (Campbell and Stark, 1980).

Chemical and microbial insecticides are registered and can be integrated with other pest management strategies. Carbaryl (Sevin-4-oil ^{R}), *Bacillus thuringiensis* (a bacterium), and a nucleopolyhedrosis virus are registered for aerial application; Methoxychlor-Naled (Dibrom ^{R}) and carbaryl are registered for ground sprays.

Some stands are more susceptible to outbreak. Stands and areas of repeated outbreaks should be hazard rated. High hazard stands could be altered through silviculture. The following harvest, regeneration, cultural, and corrective practices are suggested (Anon., 1978):

1. Refrain from harming or altering soil properties.

2. Harvest cuts (under even-age management systems) should be designed to protect residual stands from heat; desiccating winds; intertree competition; drastic changes in temperature, moisture and light; and physical damage.

3. Favor establishment of tree species adapted to drought (such as ponderosa pine on Douglas-fir habitat types; ponderosa pine, lodgepole pine, Douglas-fir and larch on sites capable of supporting true fir species).

4. In mature and overmature stands, harvest-regeneration cuts should be designed to establish seral species to develop new stands dominated by nonhost and less preferred host trees at maturity.

5. Maintain vigorous trees.

Preventive measures are similar to those mentioned for reducing hazard conditions. The following suggestions are for different age structured stands:

1. Thin young seral species stands one or more times to encourage their growth.

2. Harvest and establish seral species in stands composed mostly of host trees.

3. In multistoried stands with a diverse mixture of tree species, age classes, and sizes, improve growth of trees in the intermediate and lower stand levels by felling diseased and decadent trees in the overstory, followed by thinning to favor seral species.

4. Use a multiple thinning approach in pole-sized, dense, even-aged stands composed predominantly of host climax tree species. Remove intermediate, suppressed, and a few codominant trees during the first thinning. Followup treatments should be made at 3- to 5-year intervals to open up the stand gradually. Favor nonhost leave trees.

5. Try prescribed burning to destroy the unwanted understory which would develop into a high hazard stand in mature stands composed of predominantly of seral species with a distinct understory of semitolerant and tolerant host seedling-saplings.

LARCH CASEBEARER, *Coleophora laricella* (Hbn.)

The larch casebearer was discovered around St. Maries, Idaho in 1957. By 1965, it had spread throughout northern Idaho. Defoliation is still heavy in areas of the Idaho Panhandle National Forests but intensity and size of areas defoliated changes from year to year.

Defoliation remained very heavy through 1969. Severe branch die back and tree killing occurred on the Clarkia, St. Maries, Wallace, Shoshone,

Priest Lake and several other Ranger Districts. Damage was so severe that larch management was suspended on the St. Joe National Forest. Annual radial growth had decreased to 0-1 mm in many trees compared to more than 3 mm in 1958 prior to the casebearer in Marble Creek, St. Joe National Forest. This amounted to a 97 percent growth reduction (Denton 1979).

Long 1/ studied the impact of defoliation on tree growth and found each larva per 100 spurs (shoots) decreased tree basal area increment by about 30 mm^2/year.

A model has been used to quantify effects of larch casebearer defoliation on growth, development and dynamics of juvenile mixed species larch stands (Laursen and Moore, 1981). In pure stands, simulated defoliation applied during the period of fastest growth resulted in greatest volume losses. In mixed stands, simulated defoliation altered stand development and dynamics which impacted net volume production. Earlier and more intense simulated defoliation caused a net loss of over 468 ft^3/acre of larch volume over 16 years.

After 1969, casebearer populations began to oscillate. Defoliation was heavy in an area for several years, then suddenly decreased. Up to this time, natural control factors did not phase the exploding epidemic. The severe droughts of 1967 and 1968 may have caused populations to decline to low levels. Native parasites and predators began increasing and may have influenced the population decline. Wet springs with freezing periods can cause larval mortality.

Casebearer populations will probably never disappear but the duration of heavy population cycles will likely be shorter. During population increases, defoliation the following year can be predicted from overwintering larval and pupal populations in spring (Denton 1979). For instance, 136 to 236 larvae, or 81+ pupae per 100 shoots will usually cause heavy defoliation.

Management Strategies and Alternatives

Individual high value stands or groups of larch can be treated with low concentrations of malathion in May.

In 1960, the parasitic wasp, Agathis pumila was introduced into the western epidemic. It was well distributed by 1969. From 1972 to date, the following exotic parasites have also been reared and released:

1/ Garrel E. Long, Wash. State U., Pullman, Wash. Letter of March 10, 1981, to Scott Tunnock, FPM.

Chrysocharis laricinellae, Dicladocerus westwoodii, D. nearcticus and D. japonicus, Necremnus metalarus, Elachertus argissa and Diadegma laricinellum. Chrysocharis laricinellae was the most widespread and abundant of all parasites in 1980. We predict these parasites will decrease insect populations and consider this program the best alternative for casebearer management.

Denton (1979) measured effects of casebearer on young larch under five different stand densities. In practically all cases, insect populations increased as the stocking density of larch decreased. Pole-sized larch growing in the open or along edges of openings are the most severely damaged.

Casebearer is usually less abundant in areas above 5,000 ft. elevation with sudden temperature changes and late frosts. Tunnock (1970) determined that the number of larvae per 100 shoots were higher in the cedar/pachistima and Douglas-fir/ninebark habitat types; the number of larvae per 100 shoots decreased as elevation increased. An elevation of 3,500 feet may be the zone which limits the persistent development of heavy populations. In the 2,000-2,500 foot zone, radial increment decreased noticeably after 6 years of heavy casebearer feeding.

MOUNTAIN PINE BEETLE, *Dendroctonus ponderosae* Hopk.

Mountain pine beetle (MPB) has not been a problem in ponderosa and lodgepole pine stands. Epidemics usually develop in old growth western white pine stands. During 1980, the greatest numbers of attacked white pine were seen on the Avery, Shoshone, Bonners Ferry (Boulder Creek), and Clark Fork Ranger Districts (Lightning Creek). Many areas of lodgepole pine contain trees that are attaining ages and diameters conducive to MPB outbreaks (1910 burn areas).

Conditions Conducive to Outbreak Development and Damage in Lodgepole Pine

Mountain pine beetle presents the most serious threat to growing lodgepole pine throughout its range. Populations of the beetle periodically increase, and over the course of an infestation, large diameter trees are usually infested and killed first each year, as well as over the life of the infestation. During this period more than 80 percent of the merchantable volume can be killed.

The frequency of epidemics appears to be related to site quality, with stands on more productive sites becoming susceptible more rapidly than those growing on poor sites. The frequency and intensity of outbreaks in lodgepole pine are related to tree age and diameter, and elevation-latitude of the stand (Cole and Amman, 1980). In general, lodgepole pine stands are considered high hazard when average stand age is greater

than 80 years old with an average tree diameter exceeding 8 inches dbh. Tree mortality is inversely related to increasing elevation-latitude.

Phloem thickness within trees of a stand determines whether the beetle can maintain or increase its numbers. Because of the strong positive correlation between phloem thickness and tree diameter, and the relative ease with which diameter is measured, average stand diameter is used to determine stand suseptibility. Generally, trees growing on good sites (productivity class 5 = 50-80 cubic ft/ac/yr) will have thicker phloem and when infested a greater brood to parent ratio than trees on poorer sites (productivity class 6-7, 20-49 cubic ft/ac/yr and less than 20 cubic ft/ac/yr respectively).

Stands of lowest density have the greatest proportion of the large diameter trees with thick phloem. Therefore, beetle production will be greater in trees of succeedingly larger diameter classes in more open stands. Mortality in these stands will be proportionately greater than in dense stands.

Intensity of infestations and subsequent numbers of trees killed differ with habitat type (h.t.) (Roe and Amman, 1970; McGregor, 1978). In northwestern Wyoming and southeastern Idaho, the _Abies lasiocarpa/ Vaccinium scoparium_ (ABLA/VASC) h.t. contained the least beetle activity--44 percent--and occurred between 6,500-8,500 feet elevation; stands in _Abies lasiocarpa/Pachistima myrsinites_ (ABLA/PHMY) h.t. had the greatest beetle activity--92 percent--and occurred between 6,700-7,800 feet elevation; and within the _Pseudotsuga menziesii/Calamagrostis rubescens_ (PSME/CARU) h.t. showed 65 percent infestation and occurred between 6,000-7,800 feet elevation.

Mortality of lodgepole pine from mountain pine beetle was related to habitat types (Pfister et al. 1977). Losses were found to decrease in the following order--Douglas-fir, spruce, subalpine fir, and lodgepole pine climax (McGregor 1978). There was little difference, however, among Douglas-fir, spruce, and some of the subalpine fir types with mortality ranging from 40 to 42 percent of the lodgepole pine basal area in trees 8 inches dbh and larger. Variation in mortality between habitat types follows what has been previously established; the more favorable the site, the thicker the phloem and consequently the greater the tree mortality provided trees are 80 or more years old.

Some researchers have found that epidemics may not develop even in large diameter old age lodgepole pine unless current (CAI) and mean annual increment (MAI) intersect, or until there is a rapid decline in CAI.

There appears to be an inverse relationship between tree mortality and incidence of dwarf mistletoe infection. Stands that have the least mistletoe infection suffer the greatest mortality. Because of the beetles' strong preference for large diameter thick-phloem trees, brood production markedly declines in trees heavily infected with mistletoe (McGregor, 1978). Roe and Amman (1970) concluded that tree mortality was more severe in relatively mistletoe-free stands, and that trees in those stands had thicker phloem than infected trees. Trees having medium to heavy mistletoe infection possess thinner phloem than uninfected trees. Beetle production declines in heavily infected trees.

Stands depleted by the beetle and not subjected to fire are eventually succeeded by more shade tolerant species--Douglas-fir at lower elevations and subalpine fir and Engelmann spruce at higher elevations (Amman, 1977). With each beetle infestation, the large, dominant lodgepole pines are killed. After the infestation, both residual lodgepole pine and shade tolerant species increase their growth. When trees are again susceptible, another infestation occurs. This cycle is repeated at 20- to 40-year intervals depending upon tree growth, until lodgepole is eliminated from the stand.

Accumulations of dead material resulting from periodic beetle infestations result in very hot fires. Such fires eliminate competitive species, and serotinous cones of lodgepole pine usually seed burned areas abundantly. Following such regeneration, the mountain pine beetle/lodgepole pine interactions would be similar to those described in the absence of fire. Fires may interrupt succession at any time, reverting the stand to pure lodgepole pine.

In other stands, lodgepole pine may be more persistent or even climax. In such cases, the forest consists of trees of different sizes and ages, ranging from seedlings to mature and overmature trees. In these forests, the beetle infests and kills trees as they mature. Openings created as a result of larger individuals being killed are seeded in by lodgepole pine.

This cycle is repeated as younger trees reach maturity, are killed, and are replaced. This results in a mosaic of age and size classes in these stands. This may result in more chronic beetle infestations due to a continual source of small susceptible groups of lodgepole pines. Tree mortality may be less per acre during these infestations than occurs in even-aged seral stands.

Factors Conducive to Outbreak Development in Ponderosa Pine

Stand conditions usually favorable to and associated with outbreaks are:

1. Species composition--pure or nearly pure ponderosa pine.

2. Stand structure--essentially even-aged.

3. Stand age: 50-100 years.

4. Tree size: 8-12 inches dbh.

5. Stand density: stem basal area generally in excess of 150 square feet/acre.

Slow radial growth and small live crown ratios are indicators of high stand density, and consequently poor vigor. In ponderosa pine stands from the Pacific Northwest, east through the Black Hills, the first outbreaks usually occur in stands between ages 50 and 100 years, and usually in stands developing on a good site rather than on a poor site. A correlation exists between severity of tree killing and stand density. Good quality growing sites support denser stands than poor sites. It has been found that where beetle-caused tree mortality has occurred, basal area ranged from 140 square feet/acre up to 500 square feet/acre.

Over-dense stands is the overriding factor common to all observations from ponderosa pine stands. Sartwell (1971) found site quality influences which diameter classes are most affected within the stands' range of diameter classes. On class III sites [3/] the mountain pine beetle performed a thinning by killing suppressed and intermediate crown classes. On class IV sites tree mortality was evenly distributed in diameter classes, while tree mortality occurred mainly in larger diameter classes on class V sites.

Based on these findings, it was concluded that intensive competition between trees at high stand densities and its effect on tree resistance to beetle attack constitute a major factor in epidemic tree killing.

Loveless (1981) concluded from his studies in western Montana that tree killing by mountain pine beetle increases as (a) stand age increases, (b) site index increases and as (c) average ponderosa pine dbh increases. The proportion of total tree mortality in a fully stocked stand increases with stand age and site index.

3/ Site class as determined by Meyer's (1938) classification.

Forest managers can prevent outbreaks from developing and reduce tree mortality in active infestations by modifying the forest through active commercial and precommercial thinning projects.

Using silvicultural methods to reduce beetle hazard requires an understanding of the beetle, forest, and those factors favorable to outbreak development.

Most beetle outbreaks can be prevented by risk rating stands to identify those of highest hazard and then applying recommended management.

HAZARD RATING

Various systems have been developed for rating lodgepole pine and ponderosa pine stands for susceptibility to outbreak development.

Lodgepole Pine

Amman et al. (1977) used average age and diameter for lodgepole pine greater than 5 inches dbh and elevation-latitude for rating stands. By multiplying risk factors for elevation-latitude by those for average age and average dbh for trees greater than 5 inches dbh where 1 = low; 2 = moderate; 3 = high; a stand susceptibility classification is obtained. Hazard ratings are 1 to 9, low; 12 to 18, moderate; and 27, high. The following table lists these factors:

Elevation latitude		Average age LPP (years)		Average d.b.h. (inches) for LPP >5" d.b.h.	
High	(1)	<60	(1)	<7	(1)
Moderate	(2)	60-80	(2)	7-8	(2)
Low	(3)	>80	(3)	>8	(3)

For example, a stand at high elevation (hazard rating 1) more than 80 years old (3) with an average d.b.h. of 9 inches (3) has a hazard rating of 9 (1x3x3 = 9). This is a low hazard rating, despite the stand characteristics, because of its elevational position. A similar stand at low elevation (3) would have a high hazard rating (3x3x3 = 27). 2/

2/ One exception to these ranges occurs when all three factors are rated moderate, but the value (8) falls within the range of low risk. This should be considered moderate hazard for beetle potential.

Ponderosa Pine

Ponderosa pine can be hazard rated using the following criteria:

	Hazard rating		
	1 = low	2 = moderate	3 = high
Stand structure	multistoried	two storied	single storied
Average stand d.b.h. (inches)	6	6-10	10
Stand density BA f^2/ac	80	80-150	150

Management Strategies and Alternatives

Spraying standing infested trees to kill brood is not practical on an operational basis. However, green trees in campgrounds and other high value areas can be protected from attack for 1 or 2 years with Sevimol - 4® applied prior to beetle flight in July.

For all pine species, salvage logging of infested and sound dead trees is a major job during epidemic conditions. Before epidemics start, high hazard stands should be harvested and other stands should be managed to prevent or reduce mortality.

Reducing BA below 150 square feet/acre with at least a 16-foot spacing between trees will beetle-proof second growth stands. However, data in Montana shows that the BA should be reduced to 120 square feet/acre or less.

Using today's management guidelines, as exemplified by Meyer's PONYLD growth projections, visualize a site index 70 stand thinned at age 30 from 119 square feet BA to 79 square feet BA with subsequent intermediate cuts to 100 square feet BA at 20-year intervals. This stand will reach a maximum density of 134 square feet BA--still below the 150 square feet BA we consider hazardous at age 90.

White Pine Stands

Trees greater than 90 years old and greater than 10 inches d.b.h. that are diseased or slow growing should be harvested whenever feasible for they can present a mountain pine beetle problem.

Lodgepole Pine Stands

Stands where mortality is predicted to occur, or continue at a severe level, can be managed for timber in several ways. These management alternatives are dependent upon land-use objectives and whether stands are pure or mixed species, even- or uneven-aged.

Recognizing that the beetle concentrates on large diameter older trees, continuous forests can be broken up by small clearcuts. This will result in different age and size classes and reduce the amount of area likely to be infested at any one time. When individual stands approach high hazard conditions, they should be harvested. Where composition is pure lodgepole pine and form is even-aged, practices can include: (1) stocking control in young stands; (2) organized clearcutting in blocks to create age, size and species mosaics from mature stands; and (3) salvage cutting to reduce losses in stands under attack. Sanitation salvage cutting should, however, be considered only a delaying action at best. This strategy will do little to eliminate an infestation already underway. For the two former strategies to be of value, current inventory data must be used to identify commercial forest land which is vulnerable but not yet infested; and stands which will attain susceptible size and age within about 15 years.

Many uneven-aged lodgepole pine stands occur as mixed species stands. They contain a mature-to-overmature lodgepole pine overstory and an understory of a mixture of shade-tolerant species and younger lodgepole pine. Another common situation is one or more other species occurring in the overstory with lodgepole pine and climax species in the understory. Mature stands which are uneven-aged or mixed with large lodgepole pine in the overstory can be clearcut as a preventive; or if already infested, losses can be reduced by salvage cutting. Immature stands are candidates for stocking control with species discrimination possible in older mixed species stands.

Discrimination against lodgepole pine is possible in older mixed stands by removing only susceptible lodgepole in a series of partial cuts.

Partial cutting of large diameter trees can reduce infestation potential of susceptible stands. However, partial cuts will be effective where only a small proportion of the trees are in diameter and phloem thickness categories conducive to beetle population buildup and where enough vigorous trees remain to maintain stand productivity (Amman,1976). Maintaining adequate growing stock in such a stand may require a subsidy of development costs.

Susceptible lodgepole pine stands will maintain good productivity when either partially cut or attacked by mountain pine beetle unless the residual stand is less than 50 years old. Beyond that age, periodic annual increment steadily declines for most lodgepole pine in such stands; overstory removal may be better than partial cutting for growth of the understory. Future productivity could be seriously reduced by logging damage, dwarf mistletoe infection, and windthrow--depending on which cutting practices are used. For these reasons, managers should be cautious in the use of partial cutting where maintaining a sustained timber productivity is desired.

Partial cutting can be applied as a last resort salvage of beetle-killed trees. An increased utilization of sound material and a degree of direct control by removing beetle-preferred trees provide time to accomplish block cutting.

When implementing a partial cut to reduce stand susceptibility, two factors must be carefully considered to avoid doing more damage than mountain pine beetle would:

1. Only those trees that are preferred by the beetle should be removed. Guidelines have been developed by Cole and Cahill (1976) and Amman et al. (1977).

2. Beetles apparently remove from the stand the faster growing genotypes because they have thicker phloem. Consequently, these trees will be removed during a partial cut. Despite the beetle's preference for these trees, they should be regenerated in the stand because they put on volume faster and are the most vigorous. As these trees are removed from the stand, seed should be collected for onsite regeneration.

An additional management alternative for particularly susceptible stands is to favor nonhost trees such as Douglas-fir. Stocking will be reduced less in stands of mixed composition than that in stands of pure host type should an outbreak develop. The beetle infests lodgepole pine in a mixed species stand as readily as in a pure one, but proportion of total stocking affected will be reduced. Conversion to another species may, however, result in depredations by insect pests of that species when those stands mature (McGregor 1978).

SPRUCE BEETLE, *Dendroctonus rufipennis* (Kirby)

On the Idaho Panhandle Forests, there are not many areas left that contain high concentrations of old growth or merchantable size spruce. Most of the residual spruce is in belts or pockets along drainage bottoms. The only current outbreak of spruce beetle is in several drainages in the northwest section of the Bonners Ferry District along the Canadian border.

Some current impact data from the Bonners Ferry District shows the spruce beetle killed about 0.5 trees per acre in Canuck Creek and from 0.4 to 1.2 trees per acre in Grass Creek.

All known major outbreaks of the spruce beetle originated from stand disturbances. Areas experiencing widely scattered blowdown are conducive to increases in beetle populations. Logging operations resulting in slash accumulations, high stumps, or decked but unremoved logs also initiate population buildups. Where large stands of mature spruce are harvested in successive years, spruce beetle problems are more likely to occur. With proper management serious outbreaks may be prevented.

The spruce beetle prefers downed material to standing trees. The size of a downed tree is less important than the exposure of its bark to sunlight or contact of the bark with the ground--both of which reduce susceptibility. If downed material is unavailable, standing trees may be attacked.

Large diameter standing trees (16 inches dbh) are preferred to small diameter trees (6-8 inches dbh). Most preferred are those relatively free of live branches on the basal section. These are found growing in a competitive stand where natural pruning occurs. Open growing trees without competition and with live limbs in the basal portion are less susceptible to attack (Schmid and Beckwith, 1975).

Spruce susceptibility can be rated more easily and precisely on a stand basis than for individual trees. Knight et al. (1956) outlined the order of susceptibility (in order of decreasing hazard):

1. Stands in creek bottoms.
2. Better stands on benches and high ridges.
3. Poorer stands on benches and high ridges.
4. Mixtures with lodgepole.
5. Stands containing all immature spruce.

Unmanaged stands can be rated by using the average diameter of spruce, basal area, species composition, and physiographic location; these hazard levels are recognized: high, medium and low (Schmid and Frye, 1977). Table 1 illustrates how a stand is rated:

Table 1.--Hazard rating of Engelmann spruce for spruce beetle outbreak development development

Hazard category	Physiographic location	Average d.b.h. of live spruce >10" (inches d.b.h.)	Basal area (ft)	Percent spruce in canopy
High	Well-drained sites in creek bottoms; site index >120	$\geq$ 16	$\geq$ 150	$\geq$ 65
Medium	Site index 80 to 120	12-16	100-150	50-65
Low	Site index 40 to 80	<12	<100	<50

During infestations, large, old growth trees containing most of the stand volume are killed. This results in reduced average age of surviving trees, average diameter and height of stand, and spruce component and density. Stand basal area is reduced by 25-40 percent before infestations subside.

Management Strategies and Alternatives

Infested material with significant beetle populations, could be burned, trampled, or removed.

The use of trap trees can reduce mortality in managed stands. Trap trees are living merchantable size spruce that are felled to attract beetles; they are effective up to one-fourth mile away. Shaded trap trees sustain more attacks than those exposed to the sun. Unbucked trees are more attractive since branches help shade the bole and hold it above the ground. When held off the ground, the undersides of logs attract more beetles than tops of logs do.

The number of trap trees needed depends on the beetle population and the size of trap trees. A trap tree may absorb 10 times the number of beetles than a similar standing tree does, so the number of traps will be less than the number of standing infested trees. A ratio of 1:10 (trap trees to

standing trees) should be used for static infestations, and a ratio of 1:2 for increasing infestations. Infested trees must be removed from the stand before new adult emergence, which occurs 2 years later. This program can be continued until the susceptible stand can be logged.

Precautions should be taken to reduce the possibility of a population buildup in logging residue. Some recommended practices are:

1. Cut trees as low to the ground as possible to reduce stump height, preferably less than 1-1/2 feet.

2. Cull logs and tops should be limbed and branches removed. After limbing, cull logs and tops should be left exposed to full sunlight.

3. Logs and tops should be cut into short lengths--the shorter the better. Complete removal or destruction of all cull logs and tops would eliminate significant host material.

4. If trees are full-length logged, the diameter of the small end should be 3 to 4 inches.

5. Where a substantial spruce beetle population exists in the adjacent forest, it is better to leave logging residues than to remove or destroy them immediately after cutting. Suitable logging residue will attract emerging beetles and reduce infestation of standing trees. Infested residuals must be burned or removed.

Alexander (1973) suggests several modifications in silvicultural treatments to threatened stands. If spruce beetles are present in low numbers in the stand to be cut, or are present in adjacent stands in sufficient numbers to pose a threat, any attacked and all susceptible trees should be removed in the first cut. This will remove most of the larger spruce and is, therefore, a calculated gamble in above average wind-risk situations. Subsequently, attacked trees should be salvaged.

If more than the recommended percentage of basal area to be removed is in susceptible trees, three options are available:

1. Remove all susceptible trees.

2. Remove recommended basal area in attacked and susceptible trees and accept the risk of future losses.

3. Leave the stand uncut.

If the stand is left uncut, probably less than half the residual basal area would be lost, but most of the surviving merchantable spruce would be of small diameter.

The guideline for windthrown trees is to salvage as soon as possible, or after they are infested, before hibernating adult beetles emerge. The exception is where removal encourages further uprooting at the edge of the stand. In some clearcut areas, trees have been windthrown along the edges. Within 1-2 years after having been removed because of the potential beetle threat, further windthrow occurred. Rapid removal prevented edge trees from developing wind firmness. It might be better to leave windthrown trees, even at the risk of losing a few surrounding trees. An intensive evaluation of the adjacent stand and the beetle population, using the hazard rating system of Schmid and Frye (1977) and the blowdown prediction system of Schmid 1/ would determine whether to salvage or leave windthrown trees.

Though spruce seedlings need only partial shade, full sunlight causes considerable mortality and logging infested trees may reduce the number of established seedlings below minimum stocking. The spruce component will increase in time because of two factors:

1. Even though true fir seedlings vastly outnumer spruce seedlings, the original removal of the canopy by beetles favors the less shade-tolerant spruce more than it does the highly shade-tolerant fir.

2. Animals damage leaders of fir seedlings more readily than those of spruce; therefore, spruce gains valuable height dominance. In the absence of beetles, spruce lives longer, grows larger, and becomes dominant over fir.

DOUGLAS-FIR BEETLE IN DOUGLAS-FIR

Generalized Site Characteristics and Damage

Like spruce beetle, the Douglas-fir beetle prefers windthrow, logging slash bigger than 10 inches d.b.h., fire-scorched trees, or trees damaged by ice or snow. When this material is not available following a population buildup, beetles will attack vigorous green trees. Usually, an infestation in healthy trees lasts only 3 to 5 years.

In drier portions of the Rocky Mountains, beetles attacking standing trees prefer those weakened by drought, root disease, or defoliation over fully vigorous trees. Western spruce budworm or Douglas-fir tussock moth often top kill Douglas-fir and predispose them to beetle attack. There is also an apparent correlation between root diseases and beetle-caused mortality in old growth Douglas-fir. The beetle's success in killing trees is greatest during warm, dry summers. At such times, low-vigor, moisture-stressed trees are more likely to succumb than vigorous trees on better sites.

1/ Schmid, J. M. 1981. Report in preparation.

The beetle will produce about three times as much brood in windthrow or logs as in standing trees, particularly if the windthrow is shaded. In some timber sales in British Columbia, sufficient debris, stumps, cuttings, and log butts have been left on the ground to produce enough beetles to kill eight large trees per acre. In another area, sufficient slash was left to produce enough beetles to kill 31 trees per acre.

As populations increase in logging debris or windthrow, a few beetles attack susceptible living host trees, setting up a strong secondary attraction which, in time, attracts more beetles to the area. If weather conditions are favorable, mass attack of initially infested logs or trees occurs. Though attack density is usually higher in living trees, more brood is produced in slash. When the host material becomes saturated with beetles, the population spills into nearby green trees, and an outbreak develops. That behavorial mechanism which induces mass attacks is responsible for the beetles' ability to attack and kill living trees. Sparse beetle population can be maintained in dead or dying host material. Small numbers of beetles attacking a green tree, however, are usually pitched out.

Hazard Rating Stands

A comprehensive hazard rating system is being developed for Douglas-fir stands. Presently, stand susceptibility classifications are based on characteristics associated with past outbreaks. According to Furniss et al. (1979) stand susceptibility to Douglas-fir beetle is positively correlated with the proportion of Douglas-fir in the stand, its density, and age. Outbreaks are more prone to develop in pure stands, with a basal area greater than 238 sq. ft/ac, codominant trees greater than 13 inches dbh, greater than 100 years old. Infestations are usually more intense on north and east aspects followed by west, with south aspects being infested the least. In areas surveyed, frequency of infestations were greater at midslope with frequency decreasing on ridgetops, followed by ravines, and less frequent on benches or flat ground. Mortality was greatest in PSME/PHMA habitat type, then decreasing in each of the following habitat types--PSME/SPBE, PSME/CAGE, PSME/ACGL, PSME/CARU, PSME/SYAL. Tree killing increased with slope steepness, with more mortality occurring in stands on slopes greater than 26°.

While any of these factors can limit amount of damage, high stand density may result in younger trees being attacked. Stand resistance to population expansion increases as (1) susceptible trees are killed or logged, or (2) environmental conditions improve, promoting tree growth. As beetle populations decline, the influence of natural enemies and tree resistance becomes more apparent in maintaining beetle populations at endemic status.

Management Alternatives

Preventive measures are most effective and economical in reducing damage. Most outbreaks can be prevented by thinning young stands and maintaining desirable spacing until harvest, removing susceptible material from stands following storms that result in windthrow or snow breakage, and minimizing stand susceptibility to root disease.

Stands should be hazard rated, with logging priority given to susceptible overmature, dense, decadent and diseased stands. Infested trees resulting from windthrow, wind breakage, top kill by defoliators, or fire damage, and infested logs should be removed prior to beetle emergence (before the spring following attack). Slash and cull logs (greater than 8 inches dbh) buildup should be minimized. Tree-length logging is desirable where practical. Damage to residual trees should be avoided during stand entries.

Prescriptions made for root disease infected stands should minimize both disease and bark beetle damage. Treatments that reduce root disease will reduce future bark beetle losses. If salvaging in such stands, remove trees infested with beetles before their emergence. However, view salvage and sanitation as a short-term approach to recovering volume that would otherwise be lost, and recognize that it may actually increase disease and loss rates.

2. Remedial: Infestations occasionally develop in standing trees despite precautions. In such cases, the above recommendations should be intensified. Treatments should be emphasized in high hazard stands where mortality may be highest.

FIR ENGRAVER BEETLE, *Scolytus ventralis* LeConte

This is a chronic pest in all grand fir stands of all age classes. It seeks out diseased, injured, defoliated, and slow growing firs and slash. Droughts trigger outbreaks and when epidemics develop, tree killing may continue for 5 to 6 years.

During 1980, heaviest concentrations of killed fir were detected on the St. Maries Ranger District, Coeur d'Alene Mountain, from Coeur d'Alene north to Sandpoint, throughout the Wallace Ranger District, and from Bonners Ferry along the East Side Mountains to Canada.

Estimates are made of killed grand fir trees during aerial detection surveys. In 1980, 3,593 infested trees were detected on Idaho Panhandle Forests.

To predict potential outbreak areas, grand fir stands should be hazard rated. Moore et al. (1978) developed a stand hazard index based on stand density or crown competition factor (CCF), and host tree availabilty as expressed by Diversity Index (DI). Their assumption is that as stands become denser, competition increases, trees become less vigorous, and larger trees develop stress which increases the proportion of susceptible trees. Also, pure grand fir stands are more prone to attack. Data required to derive CCF and DI can be collected during standard timber inventories (tree species, dbh, and number of trees occurring on a fixed or variable radius plot).

Mahoney et al. (1979) also found that the presence or absence of certain understory plant species or species groups could indicate site conditions favorable or unfavorable to high mortality caused by the fir engraver. They found that *Holodiscus discolor*, *Carex deweyana*, *Arenaria macrophylla*, and *Saturega douglasii* are indications of areas where *S. ventralis* will cause little mortality of grand fir. Where *Clintonia uniflora* and *Chimaphila umbellata* occur, mortality will be more extensive.

Management Strategies and Alternatives

Destroying brood by chemical sprays or cutting and burning infested trees is not practical under forest conditions. Salvage logging of infested trees and treating green or infested slash by trampling, lopping and burning will reduce beetle populations in an area. Some grand firs resist attacks by fir engravers by phloem resinosis. These resistant trees should be left as seed trees. The best indicator of resistant trees is streamers or clear pitch exuding from entrance holes.

A good correlation exists between fir engraver beetle attack and root-diseased grand fir in northern Idaho. Weakened trees maintain endemic fir engraver populations.

Control of defoliating insects; reducing the number of grand fir trees in a stand; replacing grand fir with Douglas-fir, larch, and ponderosa pine; removal of decadent trees; and other silvicultural practices aimed at maintaining healthy stand conditions will minimize fir engraver attacks.

CONE AND SEED INSECTS

Many species of insects damage cone and seed crops. Their impacts are particularly significant in areas managed for regeneration purposes such as seed production areas (SPA's) and seed orchards. Because the Idaho Panhandle National Forest has established numerous SPA's and seed orchards this group of insects should be considered in management planning regarding the regeneration of stands.

During 1978, 1979, and 1980, four SPA's (Cathedral Peak, Halfway Peak, Kelly Mtn., and Spyglass Peak) and two seed orchards (Sandpoint, and Lone Mtn.) were surveyed for cone and seed insect injury. Very little damage occurred to the cones of lodgepole pine, western hemlock, Engelmann spruce and subalpine fir. Douglas-fir cones were severely damaged, especially at Kelly Mtn. where the entire cone crop was nearly destroyed by cone worms, cone moths, and midges in 1978. White pine cones are often heavily damaged by the mountain pine cone beetle; its impact can be extreme in seed orchards managed for blister rust resistant seed. As many as 65 percent of the cones at the Sandpoint seed orchard have been destroyed by this beetle during some years.

Generally, light cone crops are heavily infested with insects and heavy cone crops have a much lower percentage of the cones destroyed. Emphasis should be given cone harvesting during years of good crops. Chemical insecticides are registered for management of some cone and seed insects. Because treatment success is so dependent upon accurate identification of the pest, selection of the correct pesticide, and proper timing of application, Forest Pest Management specialists should be deeply involved in all spray projects.

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